



## Special issue on optimization with uncertain information: a perspective of soft computing

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Optimization permeates all endeavors of human activities and exhibits a remarkably high diversity and complexity of problems and applications. There is no surprise that with the ever increasing complexity of problems, optimization comes with an inherent facet of uncertainty conveyed in different formal ways and calls for innovative approaches to produce optimal and interpretable solutions as well as deliver user-centric environments. Soft computing with its broad ornamentation of technologies of knowledge representation, learning, and evolutionary methods plays a pivotal role in the formulating and solving optimization tasks. The objective of this special issue is to highlight an ongoing research and present recent advances on soft computing for optimization with uncertain information.

There are totally twenty-eight papers included, which can be generally divided into three categories. The eight papers in the first category focus on theoretical research on uncertainty theory. Uncertainty theory is a branch of axiomatic mathematics for modeling the uncertain behaviors of human beings, which has been widely acknowledged and applied in various optimization problems. The paper “Uncertain regression analysis: an approach for imprecise observations” by Yao and Liu (2017) models the imprecise observation of the response variables by uncertain variables, and proposes an approach of uncertain regression analysis to estimating the relationships among the variables with imprecisely observed samples. In the paper “A new definition of cross-entropy for uncertain variables” by Gao et al. (2017), a new type of cross-entropy for two uncertain variables is defined, which is the integral of the difference between their uncertainty distributions on the set of all real numbers. Besides, the

symmetry and non-negativity of the cross-entropy are investigated. The paper “Expected loss of uncertain random system” by Liu and Ralescu (2017) proposes a concept of expected loss to quantify the risk of an uncertain random system, and derives a formula to calculate the expected loss via the chance distributions. The paper “A stronger law of large numbers for uncertain random variables” by Sheng et al. (2017) verifies a law of large numbers for a sequence of uncertain random variables, functions of random variables and uncertain variables, in a general case. In the paper “Stability analysis of uncertain singular systems” by Shu and Zhu (2017), it is investigated the stability of uncertain singular systems that are a special type of multi-dimensional uncertain differential equation with some constraints on the coefficients. The paper “Quadratic entropy of uncertain variables” by Dai (2017) defines a new type of entropy for uncertain variables in the form of a quadratic function, whose properties such as the translation invariant and the positive linearity are investigated. In the paper “Stability in mean for multi-dimensional uncertain differential equation” by Feng et al. (2017), a concept of stability in mean for the multi-dimensional uncertain differential equation is proposed, which is a type of multi-dimensional differential equation driven by multi-dimensional Liu process. The paper “Complex uncertain random variables” by Gao et al. (2017) proposes a concept of complex uncertain random variables which are measurable function from a chance space to the set of complex numbers.

The second category contains eleven papers, which contribute to applying uncertainty theory in solving various optimization problems. The paper “Asian option pricing problems of uncertain mean-reverting stock model” by Sun et al. (2017) investigates the Asian option, one of the most actively exotic options in the financial derivative markets, by means of uncertain differential equations. In “Pricing decision problem in dual-channel supply chain based on experts’ belief degrees” by Ke et al. (2017), a pricing decision problem in supply chain with traditional off-line channel and e-commerce online channel is considered, and three

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uncertain programming models are employed to derive how channel members should make their pricing decisions under three power structures. The paper “Valuation of stock loan under uncertain environment” by Zhang et al. (2017) investigates the stock loan, a contract between a borrower and a bank with the stock as collateral, by means of uncertain calculus. Yan and Ji (2017) investigate in the paper “Portfolio selection model of oil projects under uncertain environment” an oil project optimal portfolio selection under uncertain environment where the cash flows are described by normal uncertain variables and their uncertainty distributions are estimated according to experts’ experimental data. Gao et al. (2017) study in the paper “Lookback option pricing problem of uncertain exponential Ornstein–Uhlenbeck model” the lookback option, an exotic option that allows investors to look back at the underlying prices occurring over the life of the option, by means of uncertain differential equations. In the paper “Stable set of uncertain coalitional game with application to electricity suppliers problem” by Liu and Liu (2017), the payoffs are characterized by uncertain variables, and the uncertain coalitional game are investigated to deal with the situation that involves cooperation among the players under uncertain environment. The paper “The information value and the uncertainties in two-stage uncertain programming with recourse” by Zheng et al. (2017) studies the definitions and theoretical properties of the uncertainties and the information value in the two-stage uncertain programming with recourse. The paper “Uncertain programming models for fixed charge multi-item solid transportation problem” by Liu et al. (2017) conducts the expected value programming model and the chance-constrain programming model for the fixed charge multi-item solid transportation problem, in which the fixed charges, direct costs, transportation capacities, supply and demand are uncertain variables. The paper “Assessment of slope stability under uncertain circumstances” by Zhou et al. (2017) studies the problem of slope stability assessment with uncertain soil parameters by representing soil parameters by uncertain variables. In the paper “A new method of level-2 uncertainty analysis in risk assessment based on uncertainty theory” by Zhang et al. (2017), a new level-2 uncertainty analysis method is developed based on uncertainty theory, and discussed for both monotone risk models and non-monotone risk models. Chen and Gao (2017) investigate in the paper “Two-factor term structure model with uncertain volatility risk” a two-factor uncertain term structure model by means of nested uncertain differential equations, where the volatility of the uncertain interest rate is driven by another uncertain differential equation.

In the last category, there are nine papers that employ different ways of characterizing uncertainties in optimization problems. In these papers, randomness, fuzziness, or combination of the both are considered. In addition, some soft computing techniques are studied, including MCMC

algorithm, random forests method, differential evolution algorithm, and so on. In the paper “Establishing the relationship matrix in QFD based on fuzzy regression models with optimized  $h$  values” by Liu et al. (2017), fuzzy linear regression models with optimized parameters  $h$  obtained by maximizing system credibility are introduced into quality function deployment, in which relationship coefficients are assumed as asymmetric triangular fuzzy numbers. Qi (2017) investigates in the paper “Project duration contract design problem under uncertain information” the project incentive contract design problem with random asymmetric information, where the risk-averse contractors private construction capacity is characterized as a random variable. In the paper *Solving equilibrium standby redundancy optimization problem by hybrid PSO algorithm*, aiming at maximizing the equilibrium optimistic system lifetime of redundant elements, Chen et al. (2017) characterize the lifetimes of components as fuzzy random variables and propose an equilibrium optimization model for the standby redundancy system. The paper “Credit spread index of fixed income securities in China” by Wu et al. (2017) establishes a credit spread index and analyzes its dynamic characteristics by using GARCH model with Markov-switching process to fit the volatility of credit spread index data and estimating the unknown parameters by MCMC algorithm. In the paper “Using machine learning and big data approaches to predict travel time based on historical and real-time data from Taiwan electronic toll collection,” by using random forests method and Apache Hadoop, Fan et al. (2017) integrate a machine learning method with a big data analytics platform to predict highway travel time from the data collected from highway electronic toll collection in Taiwan. In the paper “A credibilistic goal programming model for inventory routing problem with hazardous materials,” Hu et al. (2017) study a three-level supply chain problem with hazardous materials inventory and transportation among suppliers, manufacturers and retailers, where the demands of retailers are considered as fuzzy variables, and aim to obtaining the best balance between risk and cost. The paper “Differential evolution with individual-dependent and dynamic parameter adjustment” by Sun et al. (2017) proposes a variant of differential evolution algorithm by designing a variant of mutation operator, a gradual decrease rule for population size and an individual-dependent and dynamic strategy to generate the required values of scaling factor and crossover rate during the evolutionary process. In the paper “Positioning-pricing problem of heterogeneous duopoly with uncertain consumer preferences,” Yao et al. (2017) transform the classic Hotelling model into a heterogeneous duopoly game model under consumer preference uncertainty, and obtain the optimal equilibrium by the backward recurrence algorithm and the expected equilibrium solution by mathematical expectation method. In the paper “The optimal payment policy for a firm:

Cash sale vs. credit sale” by Wang et al. (2017), the problem how a firm should choose between cash sale and credit sale is studied. Considering the relationship between demand and the inventory level, the authors study four strategies for the case of credit sale, find that credit sale strictly dominates cash sale in some cases, and obtain some observations which are quite different from their conjecture.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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